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APPLICATIONS OF COMPUTERS TO RESEARCH ON INSTRUCTION.

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THESE ARE THREE SAMPLE STUDIES OF COMPUTER-ASSISTED INSTRUCTION (CAI) IN READING AND SPELLING. ALTHOUGH THEY ARE FOR GRADE-SCHOOL PUPILS, THE PRINCIPLES APPLY TO HIGHER EDUCATION AS WELL, ESPECIALLY IN SUCH SUBJECTS AS MATHEMATICS, CERTAIN SCIENCES, FOREIGN LANGUAGE, AND ENGINEERING. THE FIRST STUDY LOOKED INTO EXPECTED LEARNING OUTCOMES. IT TOOK TWELVE 2ND-GRADE CHILDREN THROUGH 11 TRAINING SESSIONS IN REMEDIAL READING, EMPHASIZING SENTENCE INITIATORS AND SCORING BY CORRECT READING, INTONATION, WRONG READING, OR OMISSION. A TREND TOWARD CORRECT MODELING PERSISTED THROUGH ALL SESSIONS. THE SECOND STUDY SHOWED THE PROBLEMS OF INTEGRATING CAI WITH AN EXISTING SCHOOL PROGRAM, IN TERMS OF ITS EFFECTS ON TEACHERS AND THE SCHOOL'S USUAL ROUTINE. A DAILY SPELLING LESSON WAS GIVEN, COVERING CERTAIN SPELLING RULES, WITHOUT DISRUPTING NORMAL SCHEDULES. THE THIRD STUDY ILLUSTRATED THE CAREFUL EXPERIMENTATION STILL NEEDED FOR BOTH THEORETICAL AND PRACTICAL SYSTEMS, BY SHOWING HOW THE RESEARCHERS COMPARED THE RESULTS OF TEACHING PUPILS CORRECT SPELLING THROUGH THE USE OF WHOLE LISTS AND PARTIAL LISTS OF SELECTED WORDS. ALL THREE PROGRAMS FOR THE STUDIES ARE DESCRIBED IN DETAIL. THE VALUE OF CAI AS IT IS NOW AND THE AMOUNT OF RESEARCH AND DEVELOPMENT STILL TO BE DONE ARE DISCUSSED. THIS PAPER WAS PRESENTED AT THE NATIONAL SOCIETY OF COLLEGE TEACHERS OF EDUCATION (FEBRUARY 17, 1966). (HH)

APPLICATIONS OF COMPUTERS TO RESEARCH ON INSTRUCTION

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The potentialities of computer assisted instruction (CAI) are both broad and deep in terms of contributing to excellence in the educational enterprise. We in the Stanford CAI Project in reading are committed to utilizing this technological innovation to pursue a wide range of goals and are engaged, consequently, in an extensive program of research and development in CAI and its relationship to reading and related language behaviors. This paper will report some of the experiments that have been performed in pursuing our objectives.

The particular studies to be reported have been selected to illustrate the kind and nature of questions that, I believe, are typical of research and development efforts in the CAI area. We share with all educational investigators the inherent difficulties of studying the complexities of the total teaching-learning process. We readily acknowledge the milti-variate influences of combining automated hardware, subject-matter considerations, and postulates derived from learning and retention theory. Notwithstanding these complexities, our main research objective is to explore the important variables from these three areas in order to optimize the outcomes from the teaching-learning situation, and ultimately, to develop a theory of instruction. Knowing that large scaled multi-variant experiments based on classical design are beyond our resources or capability at this time, we have evolved a "boot-strap iterative" research strategy which we believe will eventually lead us to our main goal. This strategy consists of pursuing questions according to their contribution to essential stages in the development in a CAI program. The experiments to be reported represent samples from these stages and reflect priorities common to our project and to most CAI projects.

The Existence Theorem.

The first priority in developing a CAI curriculum consists of establishing that reasonable learning outcomes can be obtained while running under computer control. One must, in a sense, prove the existence of feasible learning outcomes for the given subject-matter objectives before searching for optimal setting of the variables that are hypothesized to control the desired behavior. In the study to be presented, our learning objective was to train initial readers to pronounce sentences with conventional intonation. A common reading behavior for beginners is to give "final word stress" to each of the words in a sentence (e.g., reading "That" "Is" "A" "Fan" instead of "That's a fan."). Thus we wish to teach the child to adjust his timing, pitch, and stress contours so as to read sentences with intonation patterns commonly found in speech. This learning task takes on significance when one becomes aware that no speech analysis device is a part of our CAI system or is even technologically available at this time. We depend upon our initial reader to be the speech analyzer in this experimental situation.

We do have available one of the important features of any CAI system, namely, the precise control of the timing of all learning events. The virtue and logistic nuisance of a CAI system is the required specification of all the time intervals for each of the instructional and reinforcement events within every problem. In this particular study we utilize the pacing feature of the CAI system to accelerate the reading output of the children and, consequently, cause the children to approximate the speech and prosodic features of normal speech while reading.

Our choice of learning materials facilitated, we believe, the attainment of our learning objective. We maximized the expectancy of conventional sentence intonation by selecting high frequency sentence components such as "It's a," "That's a," "They can", etc. that are utilized commonly in the introduction of high frequency nouns and verbs. These high frequency initiating sentential strings were selected from Carterette's (1965) list of multi-word units that were uttered by six-year-old children during a free discussion session. It is to be noted that these word strings are pronounced by the children as if they are polysyllabic words. In addition, young children's use of these sentence initiators is strikingly parallel to the use of pivot words by two-year-olds as discussed by Brown and Fraser (1963). To each sentence initiator we attached a noun or a verb that the children in this study had previously learned to read aloud as a single word.

After a number of pilot investigations that focused on the timing of the learning events, we found the following experimental procedure to be most promising in terms of achieving our objective. The sequence of the procedure is as follows: (1) anticipation interval: a sentence appears on a display device and the child is given one and one-half seconds with which to attempt an oral reading, (2) reinforcement interval: the audio device then plays a reading of the sentence to the child, and (3) modeling interval: the child is given 3/4 of a second to repeat the reading of the sentence. For each new sentence the cycle is repeated. In reinforcement terms, the child is expected to use self-evaluation in order to note any discrepancies between his reading and the machine's reading. The feasibility question still remains: Will the intonational behaviors of initial readers be influenced by these timing and subject-matter variables when run in a non-contingent procedure under computer control?

During the fall of this year twelve second-grade children, who had failed to read the prior year and were enrolled in a remedial reading class, were taken through eleven training sessions. The materials consisted of four sentence initiators, "It's," "It is a," "That's a," and "They can". Fifty-five monosyllabic nouns were selected from the Sullivan Reading Program Series (1964). The children were using the Sullivan materials in their remedial reading classes. During each training session the children worked through 25 of these sentence initiators. In eight of the sessions the same initiator was presented five or six times in sequence so that one might have "It's a pen, It's a rim, It's a rib, It's a pad, It's a cat" in a sequence. Three of the training sessions (Nos. 4, 8, and 11) scrambled the sentence initiators. The oral reading responses of each child were scored by two experienced teachers into one of four categories: correct reading, list intonation error, reading error, and omission error.

Figure 1 presents the results for the anticipatory interval. The mean number of list intonational error responses systematically decreases toward zero. The correct pronunciations have an upward trend toward .75 as an asymptote. The observed drop in correct performance in sessions

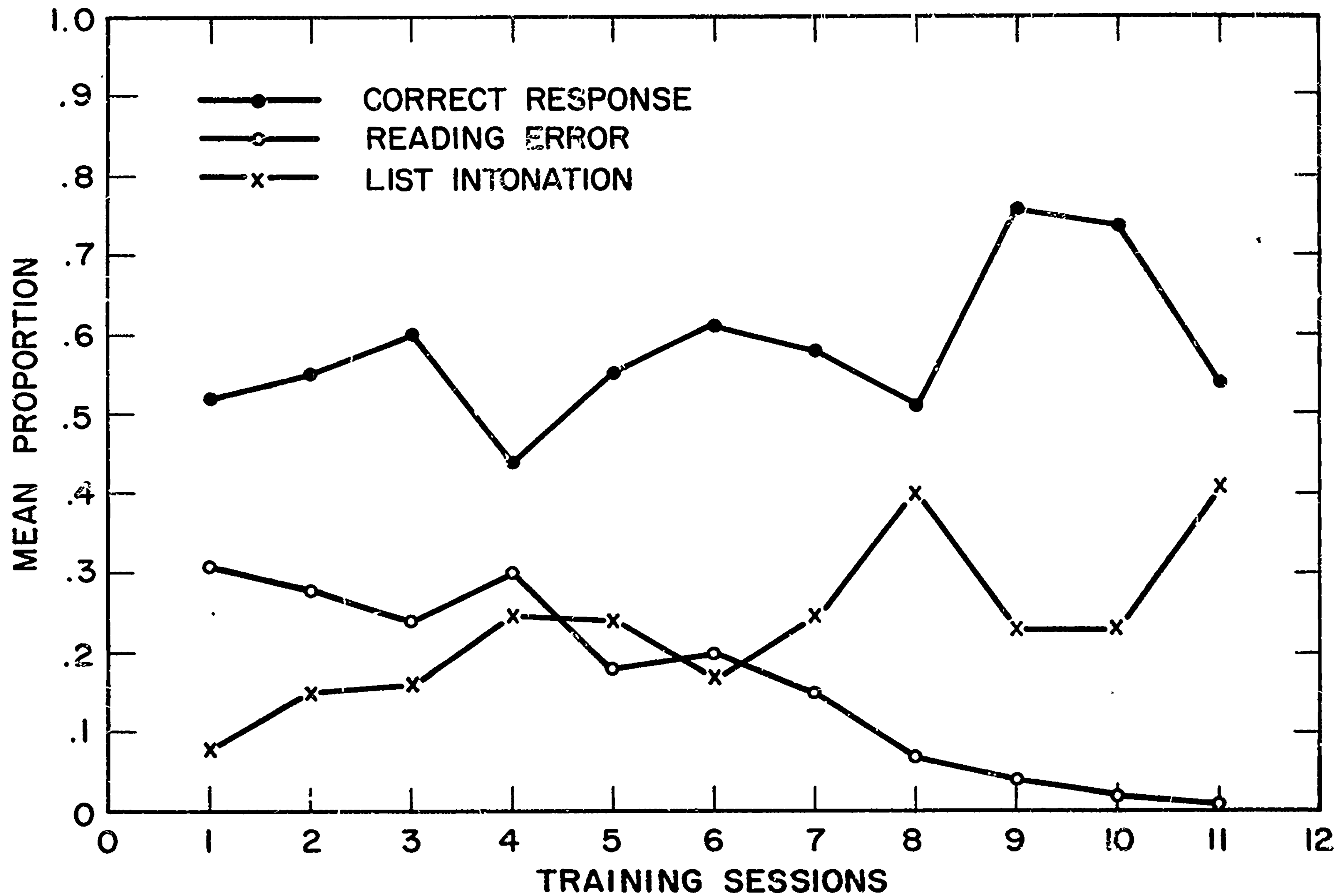

Figure 1. Group Mean Reading Responses During Intonation Training

4, 8, and 11 is undoubtedly due to the mixed nature of the list of sentence initiators. Still, it is to be noted that list intonation errors increased only during session 4 and not in sessions 8 and 11. The occurrence of omission errors was practically zero for the experiment. The reading error consisted primarily of decoding mistakes such as reading "It's a man" for "It's a mat." In our future work, we plan to delete sentences for which we have evidence that the children have not sufficiently mastered the decoding of the slot element. These results are quite encouraging to us especially in light of the small amount of training we provided the children.

The mean results for both the anticipation and modeling interval are presented in Table 1. There is a definite trend toward correct modeling that persists through all eleven training sessions. The type and amount of errors found in the modeling interval were somewhat surprising in that we had assumed that the seven-year-old children would be able to correctly repeat a reading of a fairly short sentence, such as those being employed.

We believe this study establishes the existence of reasonable learning in terms of our objectives for conventional intonational behaviors in initial reading. We make no claims that this procedure or set of materials is in any sense optimal. The results are only to be interpreted as providing evidence that a procedure of this nature and under computer control will provide reasonable learning outcomes. Secondly, we were also encouraged by the adjustment the children made to the timing features of the CAI system. We believe that for certain types of educational problems the control over the timing of learning events may prove to be a powerful variable affecting the learning outcomes. The study also illustrates how

Table 1

Group Mean Reading Responses During Intonation Training

Session	Anticipatory Interval				Modeling Interval			
	Correct	List Intonation	Error	Omission	Correct	List Intonation	Error	Omission
1	.524	.309	.077	.089	.809	.113	.041	.036
2	.546	.282	.148	.044	.824	.074	.042	.042
3	.596	.237	.157	.000	.819	.108	.019	.059
4	.442	.296	.250	.012	.867	.067	.058	.013
5	.552	.181	.239	.025	.880	047	.029	.043
6	.608	.195	.170	.018	.910	.059	.024	.018
7	.576	.146	.246	.031	.875	.069	.042	.014
8	.513	.067	.400	.020	.933	003	.057	.007
9	.757	.033	.227	.013	.887	.033	.073	.007
10	.736	.023	.226	.013	.943	.017	.027	.013
11	.543	.007	.406	.043	.970	.000	.017	.013

the well-developed abilities of children, such as speech recognition and analysis, can be used in many non-contingent learning situations. And lastly, the study is representative of a large number of feasibility investigations that we have pursued over the last year and one-half within the Stanford CAI Reading Project. I would speculate that most research and development projects in CAI also feel the necessity for performing feasibility studies of this nature.

Operational Research.

Once the CAI system is installed in running reliably, and appropriate learning materials have been programmed, the focus of development shifts to the coordination of the program with the constraints of the on-going school operation.

In planning a daily program of CAI instruction, one has to consider the effects on the classroom teacher and her daily routine. The routine of the school day at the elementary and secondary levels is far more rigid than that typically found in higher levels; consequently, one must adjust the operational characteristics of daily CAI instruction to smoothly coordinate with other on-going educational activities, and still provide an instructional contribution that will supplement or enrich the conventional activities. This study represents the outcomes from furnishing elementary-school students a daily spelling lesson that both reviews and teaches the predominant sound-to-letter rules for English monosyllabic words. Daily operational activities of this type provide the investigator the ad itional dividends of normative data in more than sufficient amounts about spelling performance. This normative data will furnish a baseline from which more detailed experimentation can be evaluated.

The teaching machine used in this study is a commercially available teletype. It is connected by private phone lines to the computer located in the Stanford CAI Laboratory. The teletype machine is located in a large book supply closet. The children reach this supply closet by a short walk from their classroom. The use of this room provides privacy for the learner and insulates the rest of the class from the operational noise of the teletype. The children have become quite autonomous in coming from the classroom one at a time and taking their daily spelling lesson.

As each student takes his turn, the machine prints out "Please type your name." The student types in his name; usually in a hunt-and-peck fashion. If the name is incorrectly spelled, the machine types out, "This name is not on the student list, please try again." A properly entered name sets the program in operation and the first problem is printed out. The machine is programmed to position itself at the first response blank. A pronunciation of the word is then given the child. A correct response is reinforced by the appearance of the next problem. An incorrect response is indicated by the word "wrong" and the problem is repeated. A second error on the problem is followed by the message "wrong, the answer is . . .," the answer being displayed. The problem is then presented once more to allow for a correction response. An error on the third presentation of a word would cause the previous message to reappear and the program to go on to the next problem. A ten-second limit per character has been set as a program parameter. If a character is not typed before ten seconds, the machine response follows the same pattern for errors except that the words "Time is up" is substituted for "wrong" at each step. This is the same program sequence used for daily mathematics work (Suppes, Jerman, and Groen, 1965). A schemata of the within-problem branching structure can be seen in Figure 2 below.

When the lesson is completed, the machine prints out for the student the following information: percentage of correct responses, a listing of the words missed, and the total elapsed time in seconds. This is followed by the message "Tear off here ________" and the paper is turned up to the cutter bar. The student tears off and keeps the printed record of his day's work.

The instructional lesson consists of the presentation of twenty-five monosyllabic words that conform to regular sound-to-letter rules (Weir, 1965). The first ten words are presented with all consonant letters being typed except for the vowels. The child's task is to insert the correct vowel letters. The 10 words are then randomized and represented to the children for conventional spelling. The lesson is finished by presenting five additional words which conform to the same vowel spelling rule. Each of these twenty-five item drills are short enough so that the children are able to complete them within three to nine minutes.

In an elementary school located five miles from the Stanford Campus, we have been supplying a daily lesson in spelling to thirty-one low-ability sixth-grade children. The mean reading achievement level of the group is 4.3 years, or approximately two years behind grade level. The children also show considerable deficiencies in spelling performance.

For this class of monosyllabic words the children typically miss about 50 percent of them when they are presented in a conventional classroom testing situation. This level of performance was established

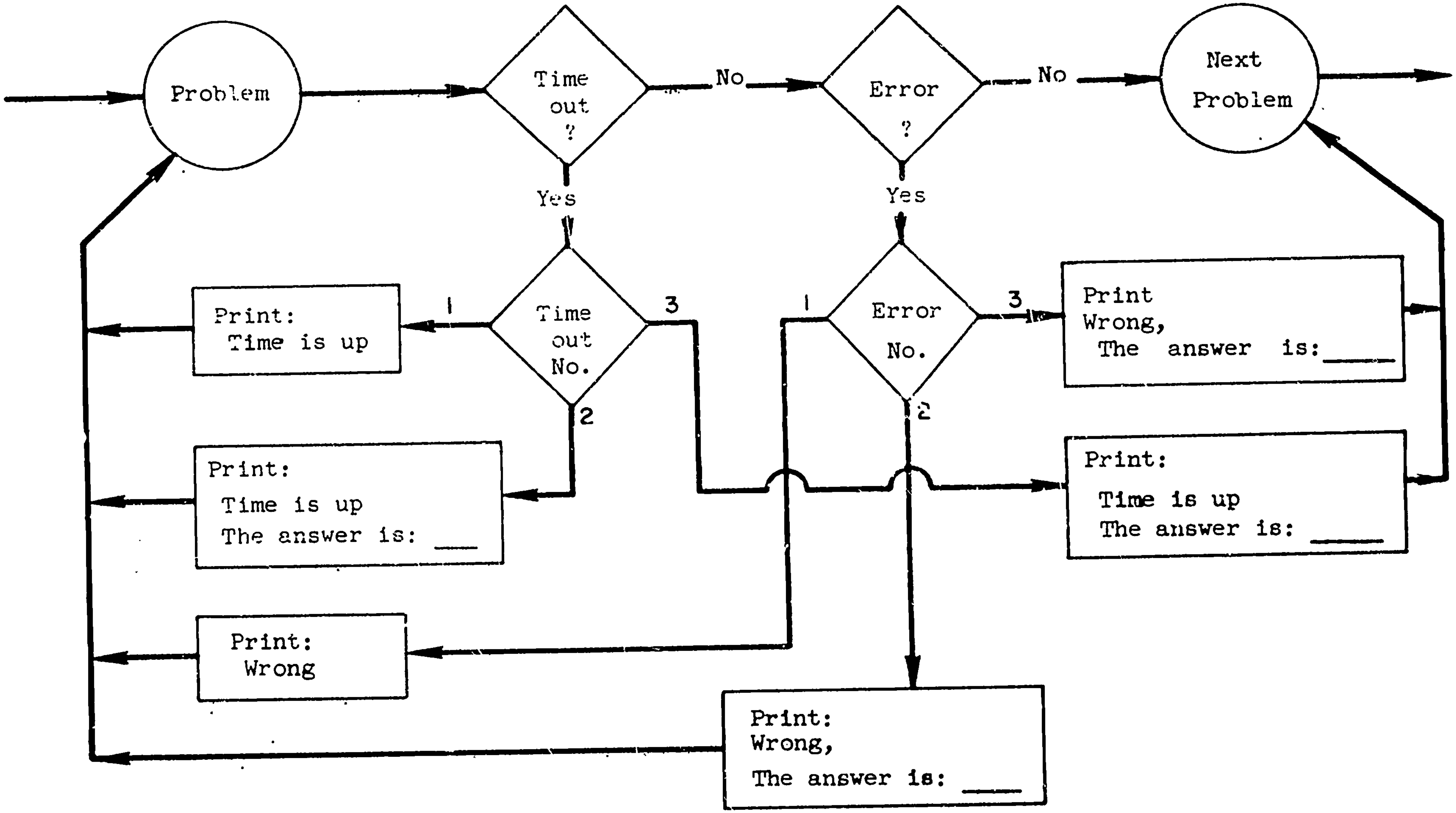

Figure 2

Flow Chart Of Program Logic For Teletype Drill Program during a testing program carried out in September, 1965. Figure 3 presents the mean proportion of correct responses to the three types of spelling items, that is vowel insertion, word spelling, and transfer words. The data covers a ten-session period for this drill work. In the first nine sessions, instruction was given on 90 words plus 45 transfer words. Session ten consisted of a twenty-five word review test, the words being a random sample from the 90 instructional words. As can be seen, there is a systematic improvement in mean correct performance. The performance is nicely ordered in that vowel insertions are simpler than whole word spelling and, in turn, transfer words are the most difficult of all. It is encouraging to note though, that performance on the transfer words is appreciably above the 50 percent level; the level at which the children normally perform.

Figure 4 presents latencies for correct and incorrect responses. The same ordering of the data takes place for latencies as was found for mean correct responding. Interestingly, where items were correctly spelled, the mean latency per character is shorter for the single vowel insertion than it is for the total word spellings. It would appear that the processing time in spelling is not some simple summation of the time to perform each sound (i.e., phoneme) to letter translation. The even longer mean latencies on incorrect responses would indicate that even more processing is involved when searching for an uncertain letter.

Due to the relatively small size of the sample, we have performed no systematic attitudinal study of the teachers' or students' reactions to the CAI program. The teacher of the children has consistently reacted with very positive verbal comments throughout this academic year. He

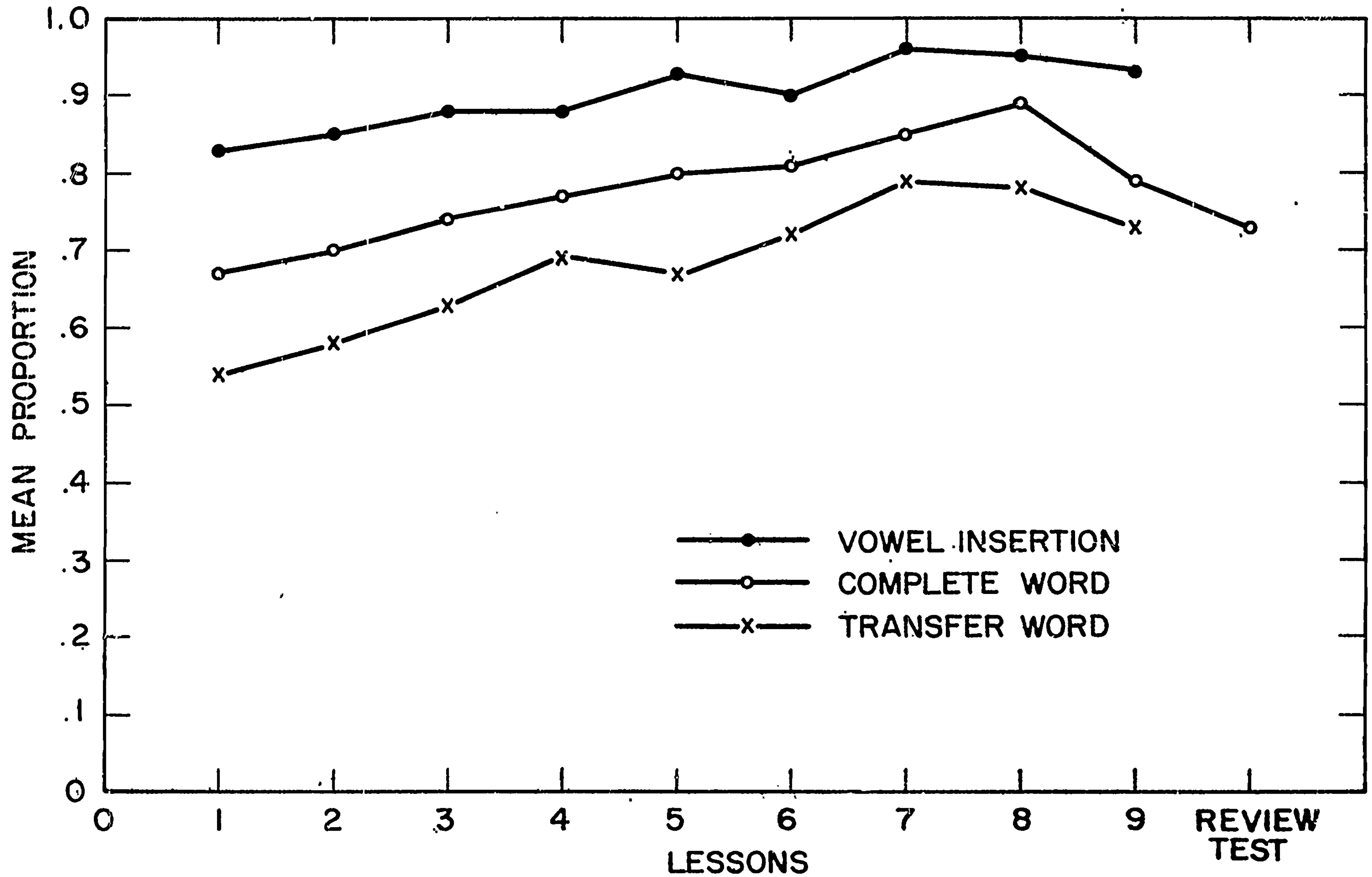

Figure 3. Group Means For Spelling Lessons.

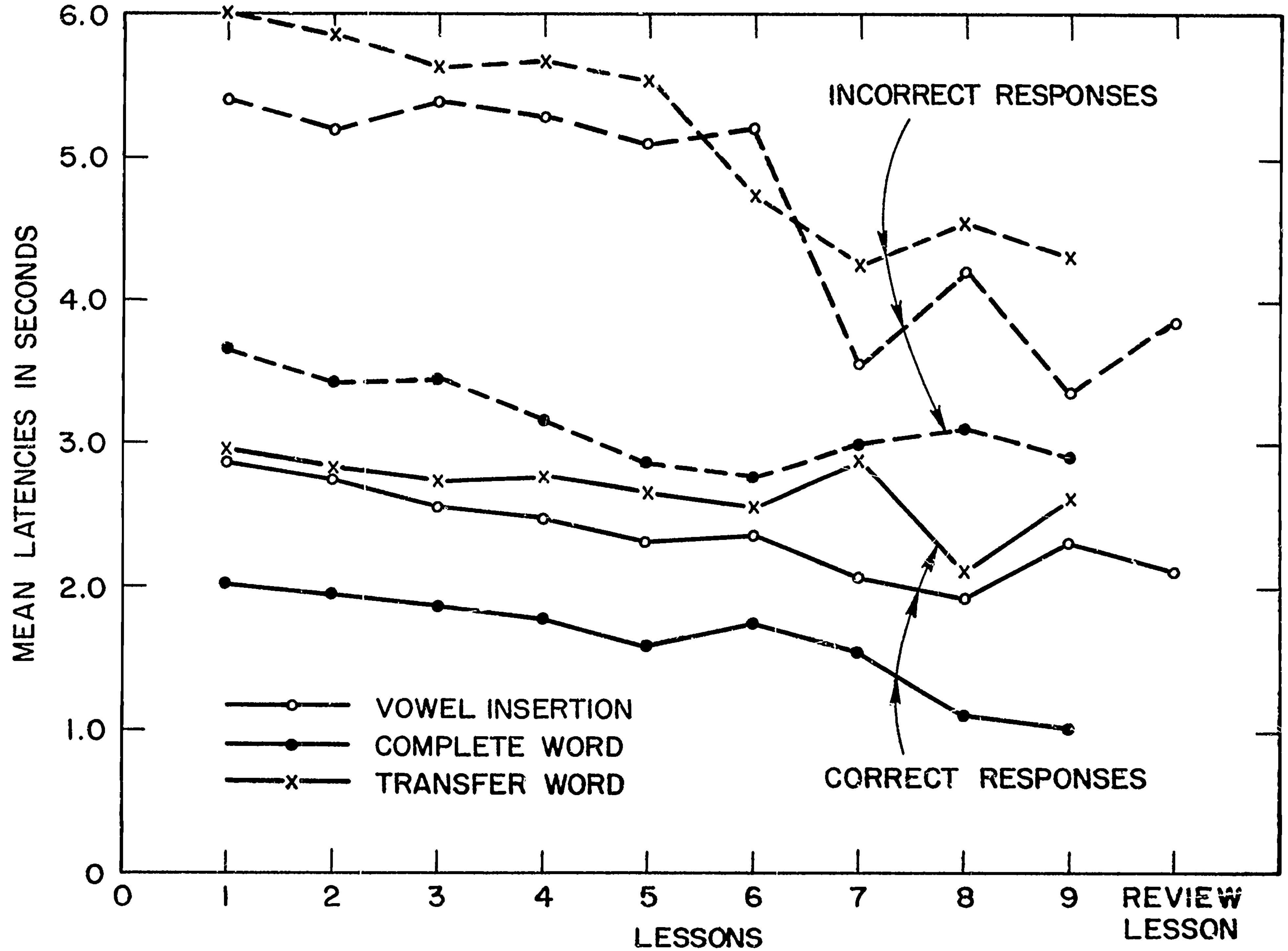

Figure 4. Mean Latencies Per Character For Correct and Incorrect Spelling Responses

scans the students' printouts daily and has modified his instructional program to highlight those spelling rules that are poorly mastered by the group. More importantly, the children have continued their positive interest in the CAI activity and are observed to apply to the daily lesson a level of attention that is undisturbed by the many visitors who have come to view the operation.

During the course of operating this CAI system on a daily basis, our experience indicates that CAI can feasibly and effectively coordinate with the conventional instructional activities of the classroom teacher in significantly increasing the spelling competencies of elementary school children. We are still investigating the nature of this collaboration between the classroom activities and the CAI activities. We desire ultimately to establish an optimal coordination between classroom instruction and CAI activities.

CAI Hypothesis and Testing

Once the CAI system has been thoroughly integrated within the school operation, one can investigate instructional variables that are hypothesized to control the optimality of the learning outcomes. In most instances these hypotheses will be related to decisions one has made in order to establish an operational basis. These curricular and operational decisions can be reformulated in most cases so as to reveal the nature of related underlying learning variables. In this particular study we investigated the role of list size and its implication for distribution of practice on the acquisition of correct spelling behaviors. More simply, is it better to practice spelling successive parts of a lengthy list of difficult words, or is it better to practice the total list? To our knowledge there has been no study of this within a spelling context (Horn, 1960). The whole-part distribution issue is reviewed for verbal material by Woodworth and Schlosberg (1954) and Ausubel (1963). Suppes (1964) has formulated the issue in terms of an optimal distribution rule that follows if a double operator linear learning model characterizes learning and retention processes. The rule can be stated as follows: If the learning parameter is greater than the forgetting parameter for a given list of items, then all items should receive a maximum distribution as in a whole list procedure in order to optimize performance on a subsequent test. The converse is true if the learning parameter is less than the forgetting parameter. In this study I predicted that the sixth-grade children would spell more accurately words practiced in three part-lists than an equivalent number of words practiced in one whole-list. The prediction follows from my assumption that the forgetting parameter would be greater than the learning parameter for these particular children when learning to spell difficult words.

In addition to the whole-part variable, we decided to evaluate the effects of the correctional variable as it is manifested in the previously mentioned problem-branching structure as presented in Figure 2. The natural opposite of this correctional variable would be a feedback condition where one indicates incorrect responses and gives the correct answer without opportunity to overtly respond. Conventional classroom experiementation indicates that correctional responses are important to spelling performance (Horn, 1947 and Tyson, 1953). Therefore, I expected the items presented under a correctional mode to be more accurately spelled than the non-correctional words. I had no insight as to the possibility of an interaction between the independent variables.

Twenty-four students from the sixth-grade class served as subjects (the other seven students were dropped from the analysis because they missed one or more training sessions). Thirty-six polysyllabic words that were inaccurately spelled fifty percent of the time by sixth-grade children were randomly selected from the Iowa Spelling Scale (1945). For each child 18 of the words were randomly assigned to the whole list and the remaining 18 words randomly assigned to the three part-lists. In turn half the words on each list were randomly chosen to receive correctional programming. Each list was then rerandomized to avoid serial effects. Parenthetically, the computer was a great aid in performing the total randomization procedures.

Each child received six training sessions, three on the whole-list and one each on the three part-lists. A twenty-four hour post-test on all of the 36 words was administered in the classroom at the end of the experiment.

Total work time for the two types of lists was held constant for each child, (i.e., the total work time for the whole-list was used to define the session length for the part-lists). Controlling work time rather than item practice seems reasonable for an educational situation in that most instructional procedures are specified in terms of fixed time intervals which are allocated within the daily routine. The conditions of the training sessions were identical to that of the teletype spelling instruction covered in the prior study. The summary statistics were suppressed at the end of each of the lessons, and the print-outs of the lessons were not given to the children. Two days prior to the start of the experiment, the children were given a 36-word test in which 18 of the words were programmed under the feedback-noncorrectional procedure. This gave the children an opportunity to adapt to this new programming feature. Lastly, half of the children were started on the whole-list in the first training session and the other half started on a part-list.

Figure 5 presents the results of the training sessions and the post-test. It is obvious from the curves that the part-list noncorrectional items were acquired with the greatest facility by the children. An analysis of variance of the post-test results indicated that the whole-part main effect was statistically significant ($P < .05$). The noncorrection main effect was statistically insignificant. The first-order interaction of whole-part by correction-noncorrection was statistically significant ($P < .01$). All of the individual difference effects were obviously significant.

The prediction from Suppes model for optimal distribution of item practice was borne out in that the children did perform significantly better on the part-list procedure. The interaction between the correctional variable and the whole-part variable can be interpreted in one of two ways. First this interactional effect might be attributed to learning factors and long-term memory effects. If the correctional procedure maximizes the permanence of a correct spelling in long-term memory, then one would expect a correctional mode to be superior for the whole-list condition, and the superiority of the non-correctional mode for the part-list condition would be attributed to short-term memory factors that become operative when a list is repeated many times within a training session. Or, secondly, the effects of the correctional branching structure may have caused the children to have a negative or emotional reaction to repeated errors. Under the part-list condition, the words are repeated in closer time intervals so that the emotional reaction to the correctional items would be heightened. Bower (1962) reports a similar reaction for college-age subjects in a paired-associate situation. At this time we feel we do not have sufficient data to decide on either interpretation. Consequently, we are now

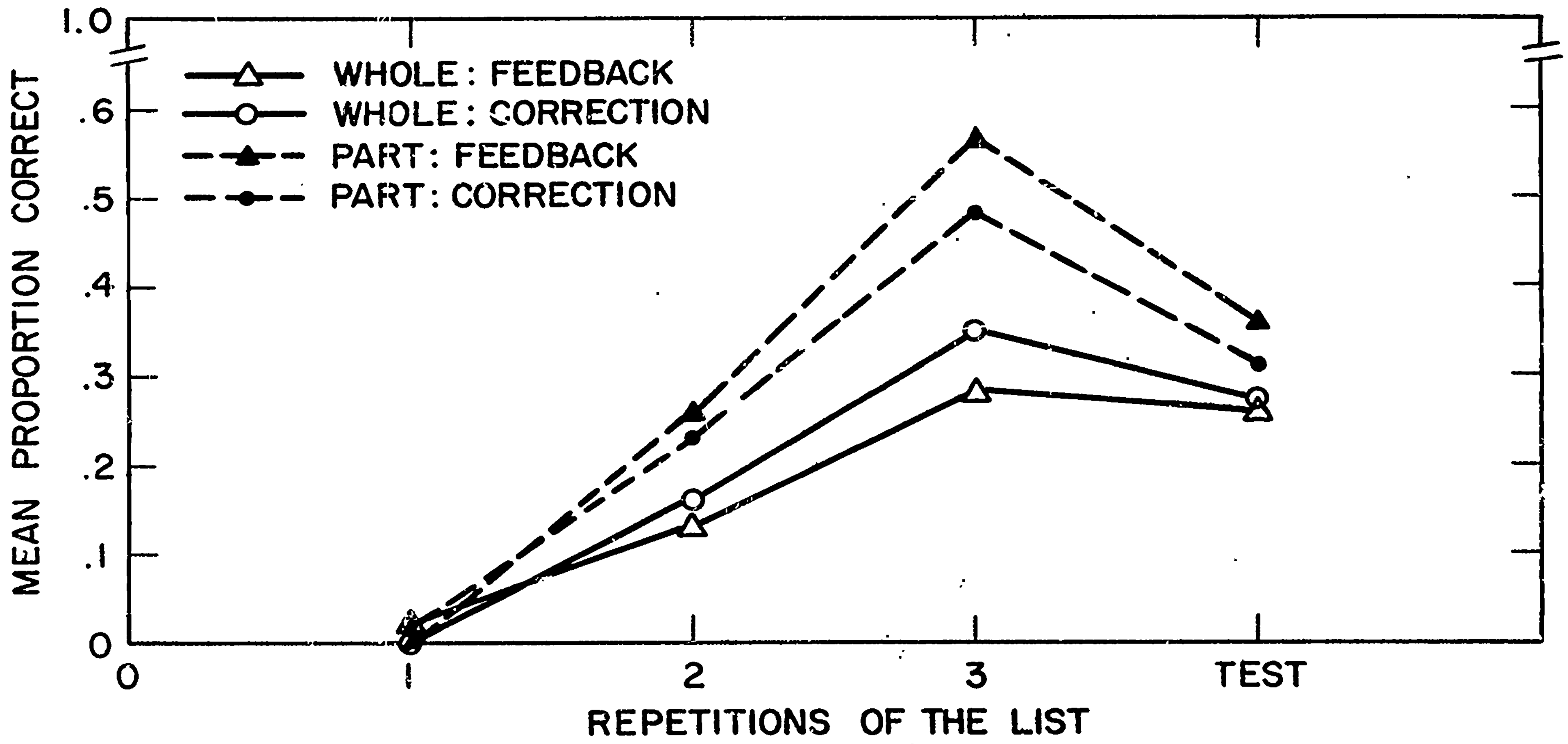

Figure 5. Mean Correct Spelling Responses For Whole-Part by Feedback-Correction Conditions

re-investigating the repetition issue in a follow-up study in which the number of within-problem repetitions and the amount of feedback are the independent variables. This experiment, though, did provide us with valuable information as to the broad parameter values of optimal list size for difficult words. As one gains more information on individual children as to their aptitudes for handling new and difficult words, one hopefully will be able to make more refined predictions as to what would be the appropriate list size for given children to practice in a spelling context.

Discussion

CAI represents one of many new innovations on the educational horizon. It shares with other innovations a major developmental barrier. After the conceptual and technological potentialities have been established by its creators, be their contributions pedagogical, scientific, or engineering in nature, the educational channels of communication are filled with rosy prophesies of the future if only the total educational structure will participate in the advantages of this proposal. These published and spoken messages stress the panacea-like characteristics of the innovation but fail in many instances to mention the required research and development stages remaining before the prophesies can be fulfilled. I would contend that educators readily accept the conceptions and possibilities of each new innovation, but fail to appreciate the substantial commitments for intricate and unaccustomed new operational orientations, patterns, and routines. Far too few are aware of the extensive research and development activities required before the benefits of an innovation become available.

It was the intention of this paper to illustrate some of the research and development activities required if CAI is to contribute effectively to improvements in educational outcomes. The three studies reviewed in this report represent samples from some of the required research and development stages. The first study provided insight into the establishment of the existence of reasonable and desired learning outcomes. The second study illuminated some of the problems, requirements, and possible outcomes when CAI becomes an integrated component of an educational operation. The third study presented some of the detailed experimentation that will contribute both to theoretical developments and to a more efficient educational system. There are, without doubt, many other additional stages in the development and acceptance of a new viable innovation like CAI.

Many investigators have reported many other types of appropriate and necessary research activities in the development of CAI, especially those that are highly relevant to higher education. We at Stanford are also investigating tutorial modes for CAI in seeking alternatives to the existing large group instructional methods. Ultimately, we all share the desire for CAI systems that will carry on Socratic dialogues between individual students and a field of knowledge. We wish to provide each student with a store of information from which he can retrieve those parts that will satisfy his intellectual needs. We as educational investigators would be fascinated to follow the course of this dialogue, monitoring and gaining insights into each increment in the learner's conceptual development. Unfortunately these sophisticated CAI systems are only at the exploratory level of existence.

At this time CAI does have the capabilities for automating the clearly specified practice requirements of courses from any level of education. In higher education disciplines like mathematics, science, foreign language, engineering, etc. are bountiful with skills that require practice in depth. How fortunate the professor or his graduate student who didn't have to grade this volume of work. Little research is required to substantiate the benefit to students who have their work evaluated while they are doing it.

Before even this level of application becomes a reality, an intensive exploration of the new roles, expectancies, and operation patterns will be needed. If this effort is forthcoming, the full potentialities of CAI can be achieved.

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